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A Design of a Filter Plant for the Removal of Iron from the Water Supply of the University of Illinois

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A DESIGN OF A FILTER PLANT FOR THE REMOVAL OF IRON FROM THE WATER SUPPLY OF THE UNIVERSITY OF ILLINOIS

BY

GUSTAV HENRY MUELLER

THESIS

FOR THE

DEGREE OF

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IN

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IN THE

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

GUSTAV HENRY MUELLER

ENTITLED A DESIGN OF A FILTER PLANT FOR THE REMOVAL OF IRON FROM THE WATER SUPPLY OF THE UNIVERSITY OF ILLINOIS.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Municipal and Sanitary Engineering.

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Instructor in Charge

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A DESIGN OF A FILTRATION PLANT FOR THE REMOVAL OF IRON FROM THE WATER SUPPLY OF THE UNIVERSITY OF ILLINOIS.

INTRODUCTION.

The object of this thesis is to design a plant for the removal of iron from the water supply of the University of Illinois. This supply is drawn from four wells in drift about 145 feet deep. There is no outside pollution and the water is excellent except for a high iron content which forms an objectionable precipitate upon exposure to air. The study of the amount and best means of removal of the iron has been taken up by Dr. Edw. Bartow of the State Water Survey, F. V. Laracus, and W. G. Stromquist and presented as thesis by these last two men. Mr. L. B. Barker has also written a thesis on the design of a purification plant for the University of Illinois water supply. The plant designed was mainly for the removal of iron. He accomplished this by coagulation and rapid sand filtration. From results of experiments worked out by the above mentioned men, it is apparent that there is no need of coagulation for the removal of iron, and the cost of the same would increase the running expenses of the plant even after installation. The water used by the cities of Champaign and Urbana contains practically the same amount of iron and experiments with this water have been carried out by Mr. Stromquist, and are now being continued by A. L. Enger and E. F. Blakeslee.

Iron in water is soluble in the absence of oxygen , except in the case of ferrous sulphate, and is deposited when the ground water is exposed to air. The sediment which forms varies in

color from black to red according to the degree of oxidation of the iron salts. There is frequently trouble from crenothrix and beggiatoa, the latter being responsible for an unpleasant odor.

This design is subject to slight alterations depending upon the results obtained by Messrs. Enger and Blakeslee in the experiments with the Urbana and Champaign city water supply.

I- GENERAL DESIGN.

In designing this plant it is desirous to keep the cost of construction low and in order to do this it is best to utilize as much of the existing apparatus now in use in connection with the present system of water supply,as possible. This consists of two steel plate storage tanks, 18 feet high and 20 feet in diameter, each capable of holding a supply of 42,500 gallons, one 16 x 9 x 12 Underwriter pump capable of pumping 750 gallons per minute, and a concrete reservoir which is used only in case of great emergency. A plan of the present plant is shown on Plate I. The best available and most convenient site for the filtration plant is just east of the pumping station on the south bank of the "Boneyard." This stream affords ample drainage for all parts of the station and it is not likely that the plant will interfere with the building of any new structures which may be put up in the future.

From Mr. Stromquist's work, it was found best to remove the iron directly by means of aeration and rapid sand filtration. In this plan , water would be pumped into the old storage tanks, discharging into the same through aerators connected to the discharge pipes from the pumps. From these tanks, the water would flow by gravity through the filters and then into the clear water well.

The natural condition of the ground makes it necessary to supply some additional head to that already available in the supply tanks. In order to increase this head the tanks must either be enlarged or else elevated on steel towers. The most simple method would be to increase the capacity by adding two additional rounds of plates at the bottom of each tank. This would increase the height to twenty-seven feet and

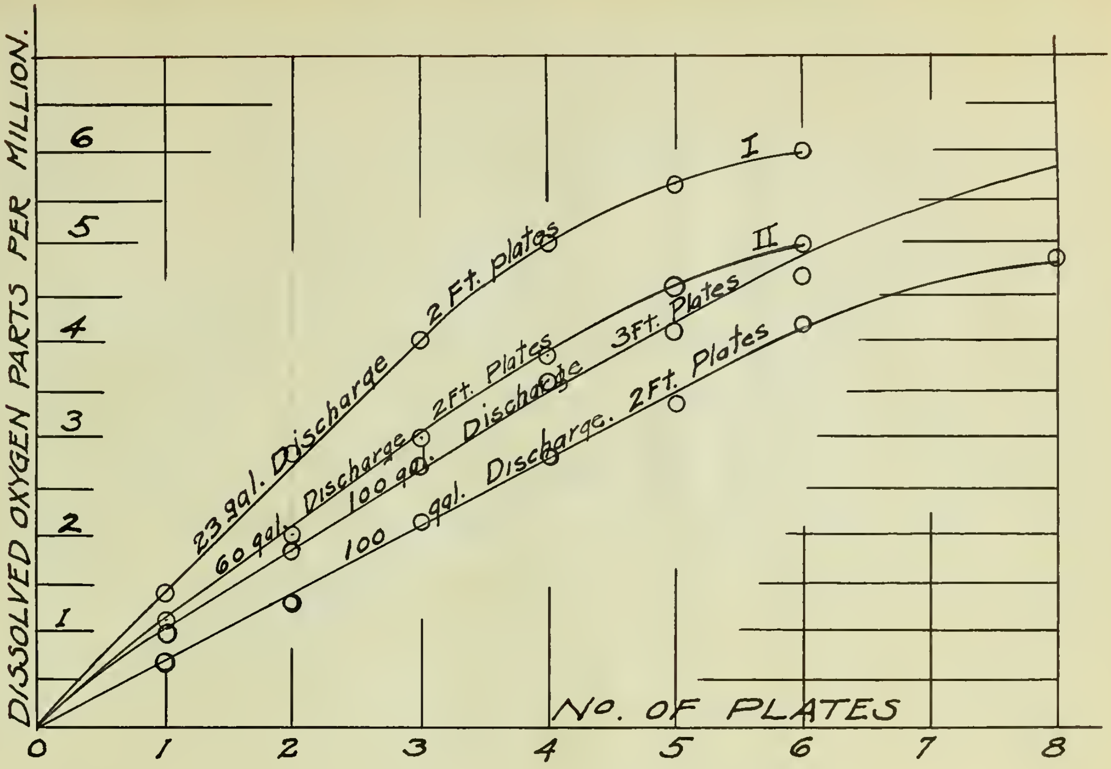
allow for sufficient head to operate the filters properly.

The maximun daily water consumptior at the University is about 200,000 gallons and two filter units are designed, each capable of handling this amount. There is sufficient room for the construction of two more units if necessary, which would increase the capacity to 770,000 gallons per day. A clear water well of 60,000 gallons capacity is built underneath the filters. This,with the water in the storage tanks, will furnish a six hour supply, allowing for any irregularity in the rate of demand and for shutting down the deep well pumps during the night.

II- AERATORS

Two general types of aerators were used by Mr. Stromquist. One, the dishpan type, consists of a series of pans one above the other, having the bottoms perforated with small holes, which which allow the water to flow from one pan to the other. The most serious difficulty with this style is that the holes become stopped up with the iron sediment and incomplete aeration is the result. The effeciency of this style is very low. The other type is made of numerous circular plates which allow the water to flow over them and discharge into a tank. This style will be used here because it is the most effecient type tried by Mr. Stromquist. The aerator is very simple ,consisting merely of circular plates six inches apart and three feet in diameter. The plates surround the six inch discharge pipe so that the water drops from one plate to another and finally into the storage tanks. The drawing on Plate II shows the aerator complete.

Very little data has been collected on the amount of aeration required and the size of aerator required to furnish the amount of oxygen which it takes to saturate a given flow. Mr. Stromquist experimented with an aerator two feet in diameter and having six pans on which the water dropped. He used different discharges and plotted curves showing the number of pans required to furnish a certain number of parts per million of dissolved oxygen.



The above curves, numbered I and II, show the results given by Mr. Stromquist. The other two are interpolated from his and show that eight pans, three feet in diameter, will be necessary to furnish sufficient air to oxidize the iron from each of the University wells which have a discharge of 100 gallons per minute.

III.- FILTERS.

In the design of the filters a nominal rate of I25,000,000 million gallons per acre per day was used. This rate was decided upon , because from Mr. Stromquist's experiments a rate of 250,000,000 gallons per acre per day showed a loss of head nearly four times greater than with the I25,000,000 gallon rate. Then,also, there was plenty of space available, which would furnish the necessary supply at this lower rate. With a rate of I25,000,000 gallons an area of 70 sq. ft. is necessary to take care of the maximum daily supply. Two units, each 7 x I0 feet,were designed. This will leave one unit entirely out of use in furnishing the daily consumption of 200,000 gallons. In this way a means is afforded whereby the sand may be removed and cleaned without causing any shut down of the plant. The floor space back of the filters over the clear water well can be utilized for washing the sand. There is sufficient room alongside of these two units for the construction of two more , if for any reason the demand should increase.

The filtering material consists of a sand layer, three feet thick underlaid with a half a foot of graded gravel covering the under drains. The effective size of the sand should be about .76 to .85 millimeters with the uniformity coefficient of 2 to 3. The gravel should be graded from 3 to I2 millimeters and a wire screen is to be placed between the sand and gravel. The size of sand and gravel to be used was determined entirely from the results obtained by Mr. Stromquist in his " Report On the Removal of Iron From the Water Supply of Champaign and Urbana." He tried the removal

by gravel alone and by sand alone with the results shown in the following tables:-

IRON REMOVED BY GRAVEL FILTERS.

Depth of Gravel Feet	Removal of iron Per cent
I	24.0
2	37.0
3	45.0

The gravel was coarse gravel which passed a 2-mesh screen and was caught on a screen with 3 meshes to the inch. The rates for the experiment varied from I55 to I56 million gallons per acre per day.

IRON REMOVED BY SAND FILTERS.

Depth of Sand Inches	Removal of Iron Per cent	Rate of Filtration Million gal. per acre per day.
I5	66	98
27	7I to 98	I25

The removals given are the averages for a series of tests. The sand was screened from what is known as " Torpedo Sand" and the part was used which passed an 8 - mesh screen and was caught on a twelve mesh screen.

The difference in elevation between the top of the sand in the filters and the high water level in the storage tanks is twenty two feet. Eight feet of water in the bottom of the tanks

will not be utilized because the filters are built above the ground. The water level on the filter is to be maintained four feet above the surface of the sand by means of a butterfly valve in the filter influent pipe which is operated by a float. A loss of eight feet in the filter and under drains is allowed before washing is necessary. According to the experiments that have been made, it will probably not be necessary to wash the filters more than once a day. The amount of wash water required will vary from two to three percent of the effluent and ten minutes will be enough time to allow for every cleaning. The washing is to be done with filtered water. There is no means of sand agitation provided except by the water coming up through the under drains under the relatively high pressure of three or four lbs. per square inch. The sand is to be treated with a solution of hypochlorite of lime and thoroughly washed whenever the filters seem to be clogged. This treatment with bleaching powder was tried by Mr. Stromquist and it proved very satisfactory. He found in his work on city water that after the filters had been in operation for some time the final effluent contained some iron. This was due to the growth of organisms upon the sand which took up the oxygen, and interfered with the oxidation and precipitation of the iron. By this system of washing it will be unnecessary to use any compressed air for the agitation of the sand when cleaning.

The piping for the system is shown on Plate VII. The connections for only one filter are drawn, the piping being symmetrical about the gallery for both units. To distribute the

flow more uniformly over the filter area and to reduce the velocity of the entering stream, a box-like affair is fitted onto the end of the influent pipe. Plate II shows the box in detail.

The filtered water is drained off by holes through the floor , spaced both longitudinally and across the filter. After passing through these, the water is collected in a chamber with a concrete slab bottom, which slopes toward the center from each side at an angle of one foot in five. This bottom also slopes toward the front of the filter having a fall of eight inches in ten feet, the water there being drained off by an eight inch effluent pipe . Plate VI shows the details of this collector system. The flow through the filter is kept constant by a controller attached to the effluent pipe, placed in the pipe gallery. After passing through the controller,the effluent flows directly into the clear water well. underneath the filters. As a means of draining the filters other than the effluent pipe, a six inch pipe is connected to the effluent pipe by means of a tee just outside the wall and this enters a main ten inch drain running along the floor in the center of the pipe gallery.

As was stated the washing is done by means of filtered water under a pressure of three to four lbs. per square inch taken by means of a pressure reducing valve from the mains. A six inch pressure pipe is located on one side of the main effluent pipe and connections made with the filter effluent near the gallery wall. The dirty water is drained off by means of gutters placed along the lateral sides of the filters. These two gutters are connected by a third trough whose bottom slopes toward one end where it connects with a ten inch drain pipe. These gutters are steel troughs,

unsupported save at the ends which are imbedded 4 inches in the walls. This will allow for a maximum lateral movement of the dirt particles of three and one half feet which is not too large to readily carry off the washing.

IV - CLEAR WATER WELL.

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The question of a design of a clear water well of large capacity does not enter into this problem as it does in the design of most purification plants. The water is not contaminated by any outside source and the use of raw water for a certain length of time would not be harmful. In case the filters were shut down, the water could be pumped directly into the mains from the supply tanks each of which will hold 63,500 gallons after the height has been increased. In case of fire or instances where a larger amount of water is required, for a short time, than that which the wells supply, the water in the reservoir which is always connected can be brought into use. This reservoir has a capacity of 110,000 gallons, its sole purpose being to keep a supply on hand for fires. A well of 50,000 gallons storage is designed and this is sufficient to supply the demand for three hours during the day, very little water being used at night.

The question of location of the clear water well is governed largely by the peculiarities of the site chosen for the filters. The only two available places for the well separate from the filters are across the "Boneyard" along side the Mechanical Engineering Laboratory or on the other side of the pumping station adjacent to the reservoir. In both places it would be necessary to construct long suction pipes which would not be desirable.

Several of the large plants throughout the United States, such as Albany, N.Y., Cincinnati, O., and Columbus, Ohio, have their clear water wells underneath the filters. Such a plan was adopted in this design. It involves a rather complicated

arrangement of walls and supports for the filters but it has the advantage of being compact and economical. Here the difficulty of excavating much below the "Boneyard" prevents a very great depth being economically reached, but allowing for a loss of I0 feet in the filters and through the controller, a working depth of I2 feet can be easily obtained. In order to give the required capacity with the length of the well equal to the length of the filter building, it will be necessary to run the well back I8 feet from the front thus making it extend II feet beyond the filter. The space above this extention may be utilized for storage and sand washing. The floor is at the same elevation as the floor of the pipe gallery.

The floor of the clear water well is so constructed that it slopes toward the South west corner. Here is located a sump from which a I0 inch suction pipe leads to the pressure pump.

V - CONSTRUCTION.

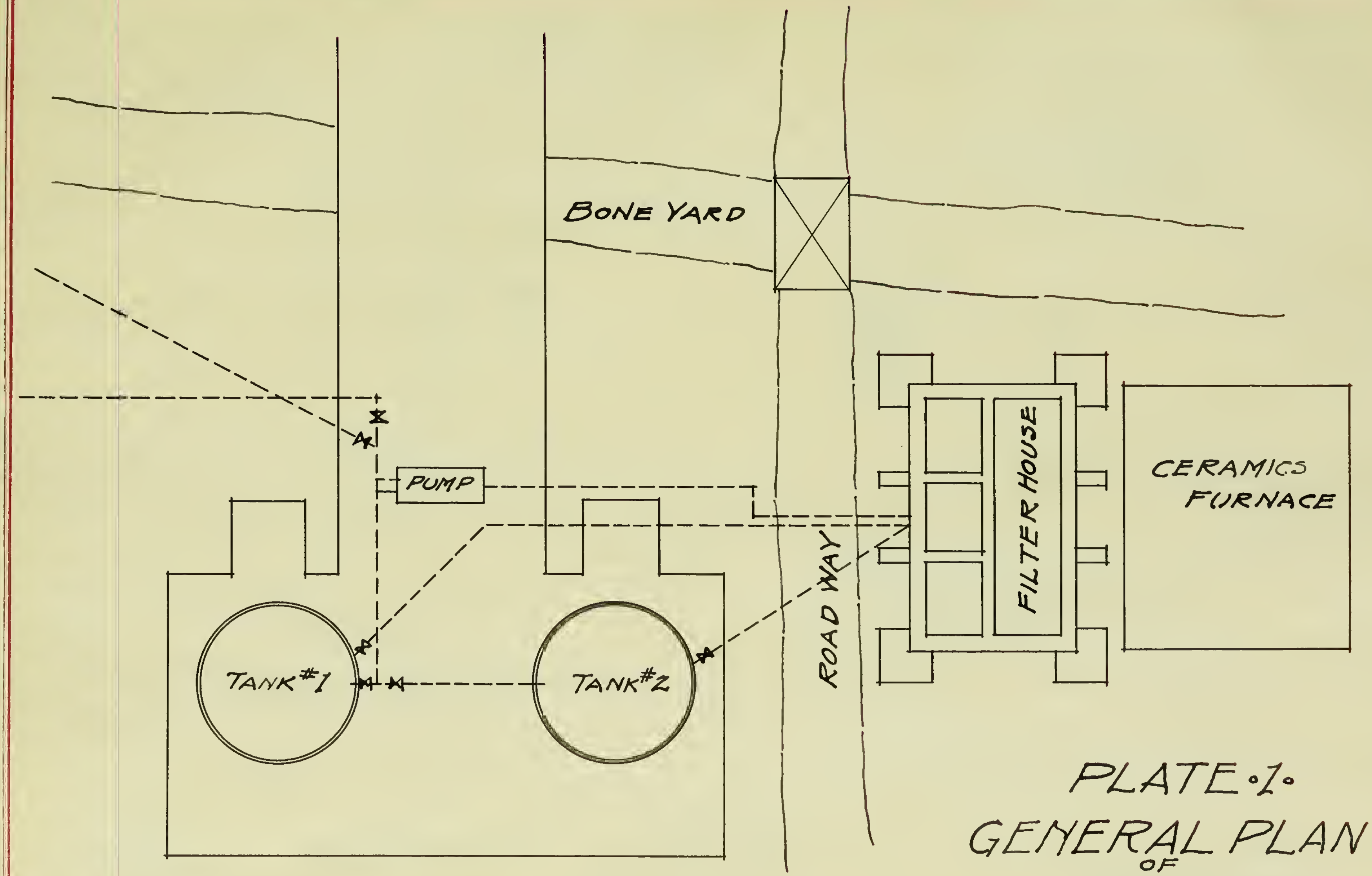
The walls and floors of this plant are designed to be built entirely of reinforced concrete. A working stress of 12,500 pounds per sq. in. for the steel and 600 pounds per sq. in. in compression for the concrete was taken. The reinforcing rods near the front were taken one and one half inches from the surface.

The outside walls of the plant are designed in two separate sections. The top 8½ ft. is designed to withstand a head of eight feet of water and the bottom 17 ½ ft. to withstand a head of 16 ft. of water. Heavy buttresses at the corners and at the end of the pipe gallery walls take up the overturning moment. The buttresses are two feet thick and the reinforcement consists of horizontal bars running nearly through the wall, thus binding the wall and buttresses together. The walls themselves are designed as simple beams the length being taken as the distance between buttresses. The inside filter and pipe gallery walls are designed for an eight foot head of water.

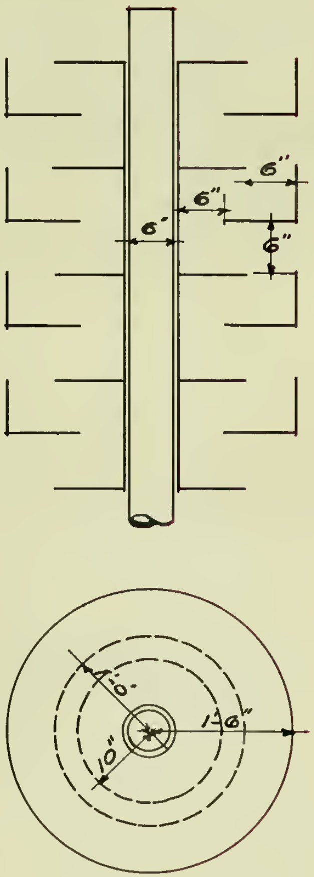
The floor of the clear water well is to be reinforced concrete six inches thick. The floors of the pipe gallery and filters are designed as slabs six inches thick supported by the walls. The floor of the storage room is to be of concrete supported by six inch steel I beams spaced eight feet center to center and reinforced with small rods.

VI - PUMP

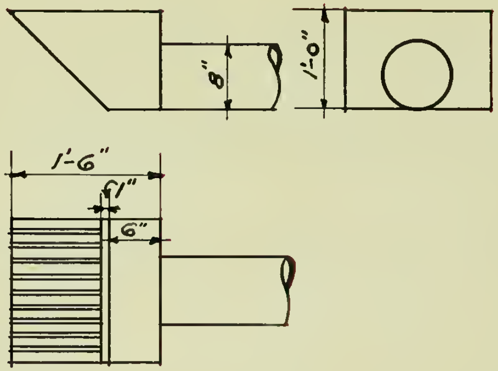
Provided the University does not put in a new pump of greater capacity than the present one before the filter plant is built it will become necessary to include a pump of 2,000 gallons per minute capacity in the design of this iron removal plant. This is needed to take care of the washing of the filters. A cheap and efficient pump for this service would be one of the centrifugal type.



PLATE·1·
GENERAL PLAN OF PLANT
SCALE 1"=20'-0"



AERATOR



BOX ON FILTER
INFLUENT PIPE

PLATE II

SCALE ½" = 1'-0"

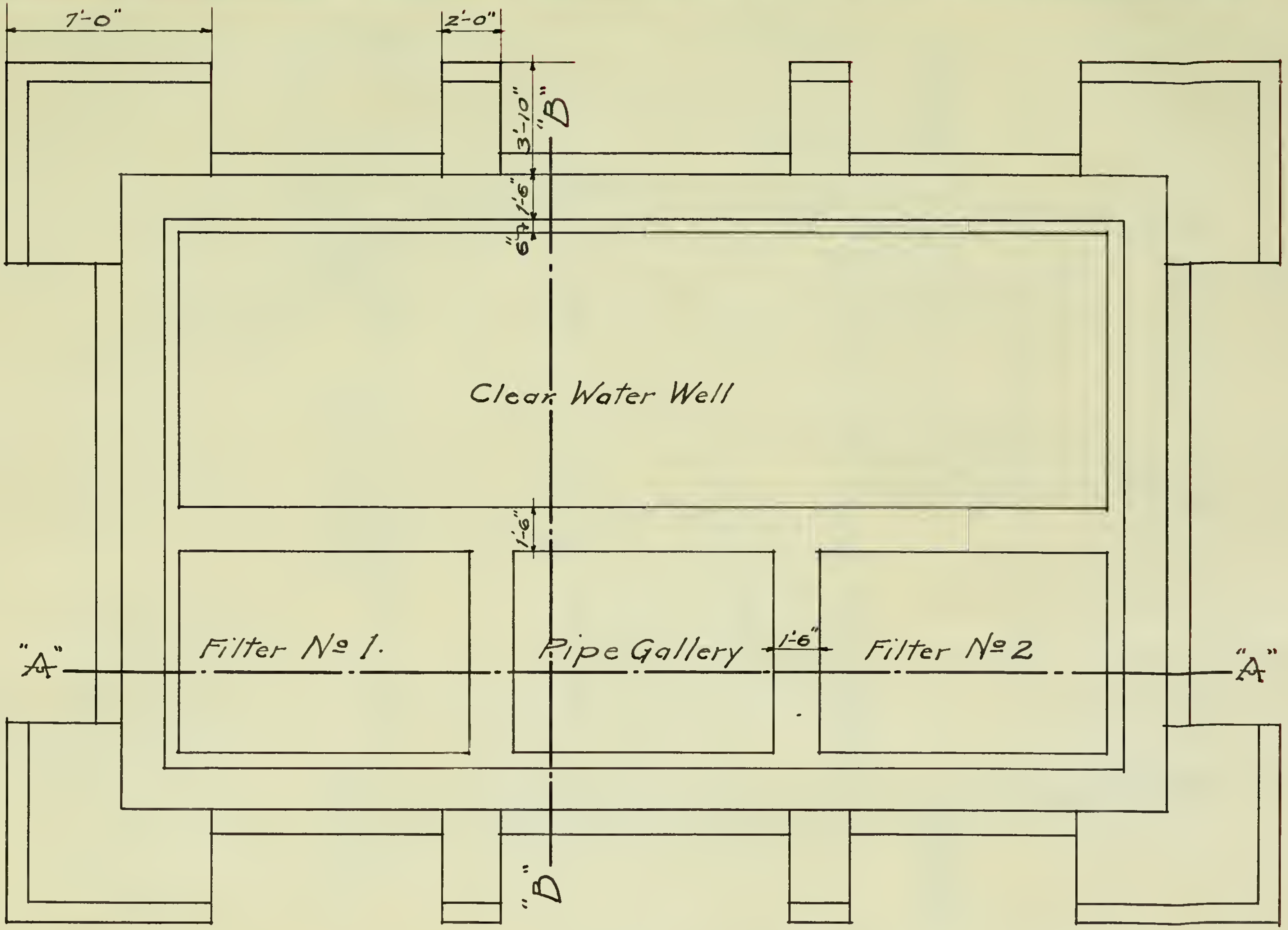


PLATE III

PLAN OF FILTER SCALE 3/16" = 1'

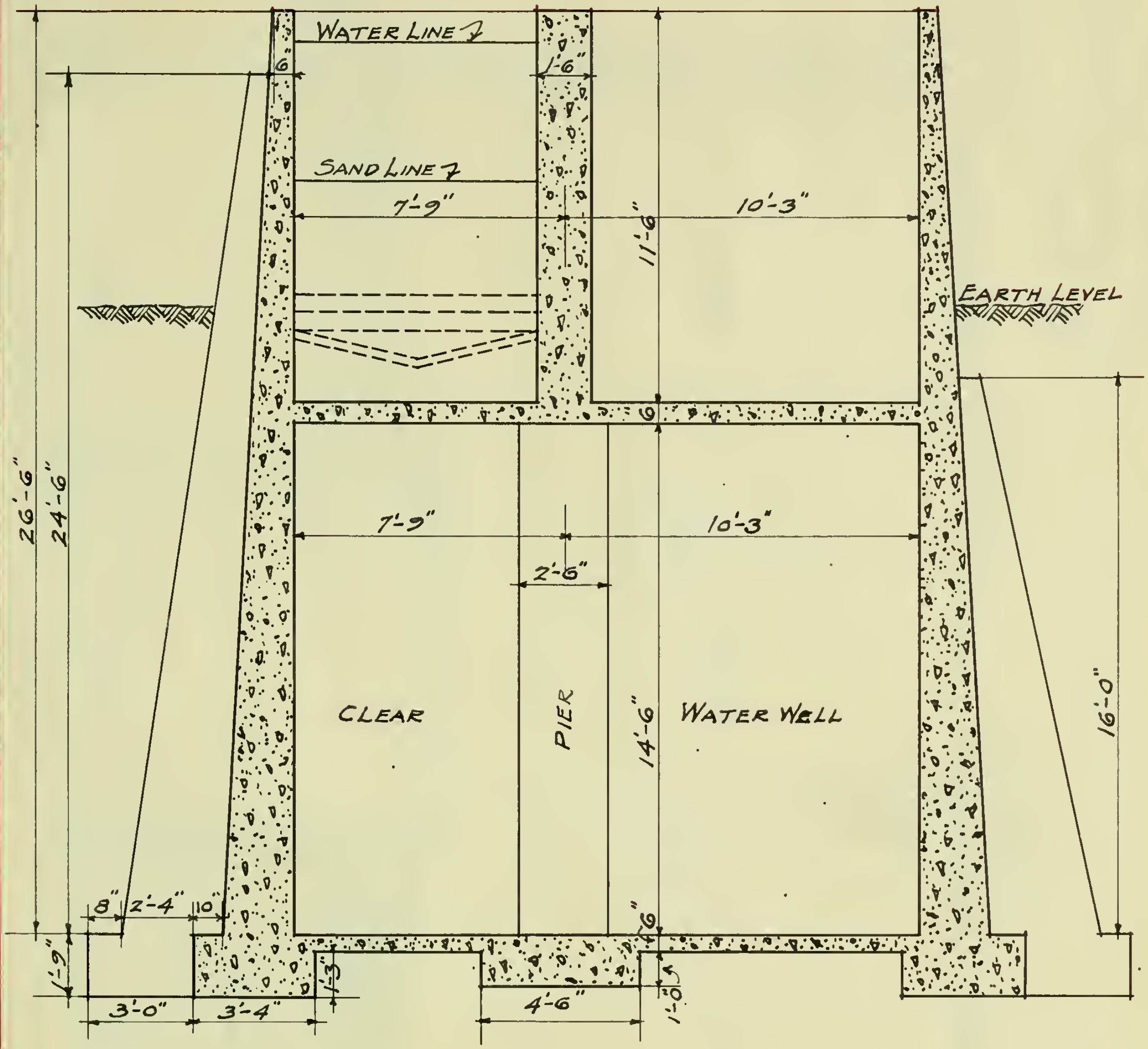


PLATE IV
WALLS OF FILTER
SECTION "B-B"
SCALE 1"=5'-0"

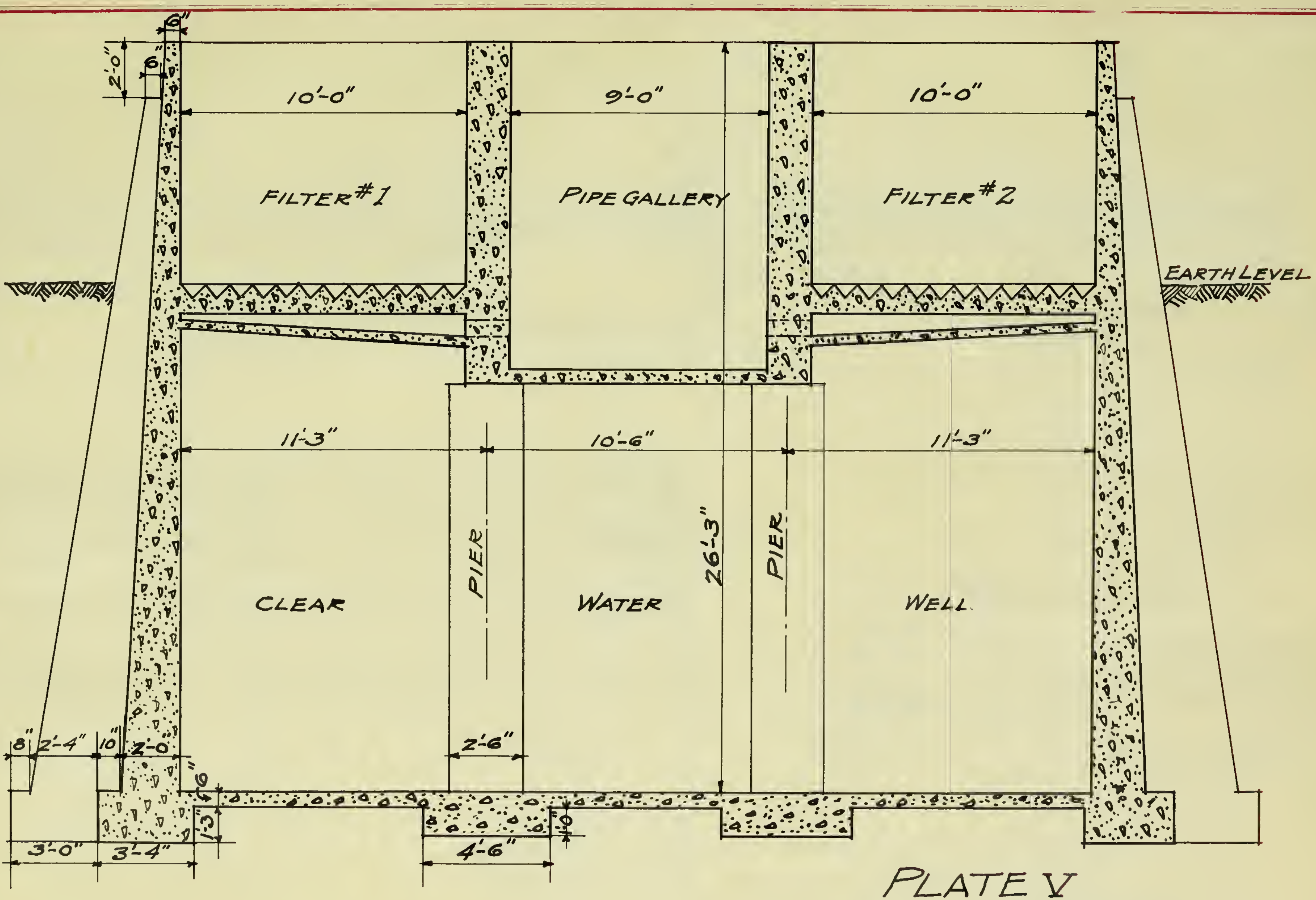
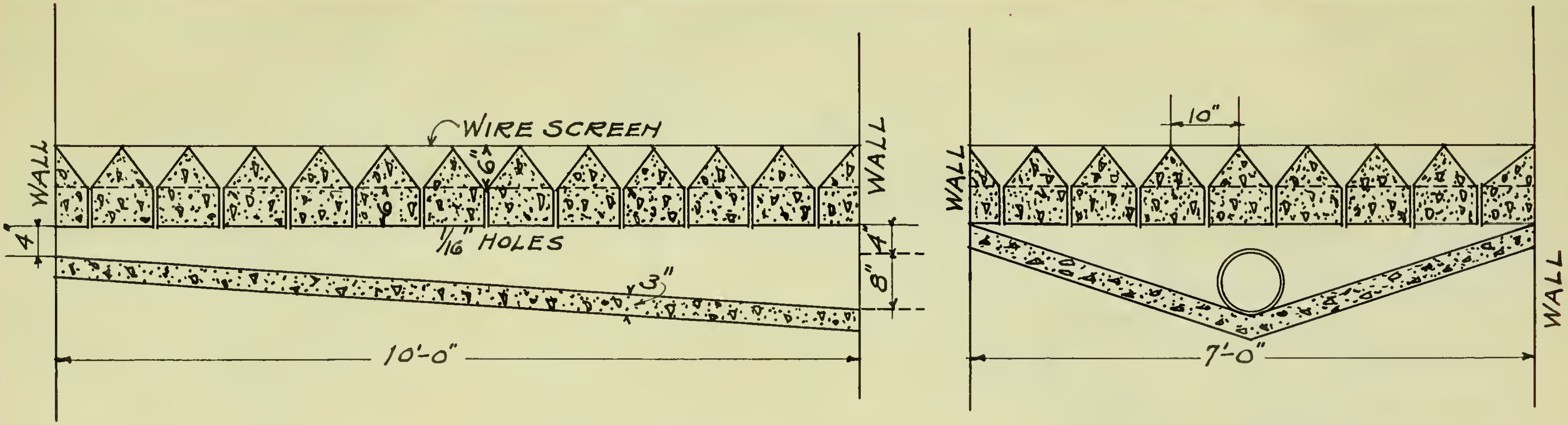


PLATE V
WALLS OF FILTER
SECTION "A-A"
SCALE - 1" = 5'



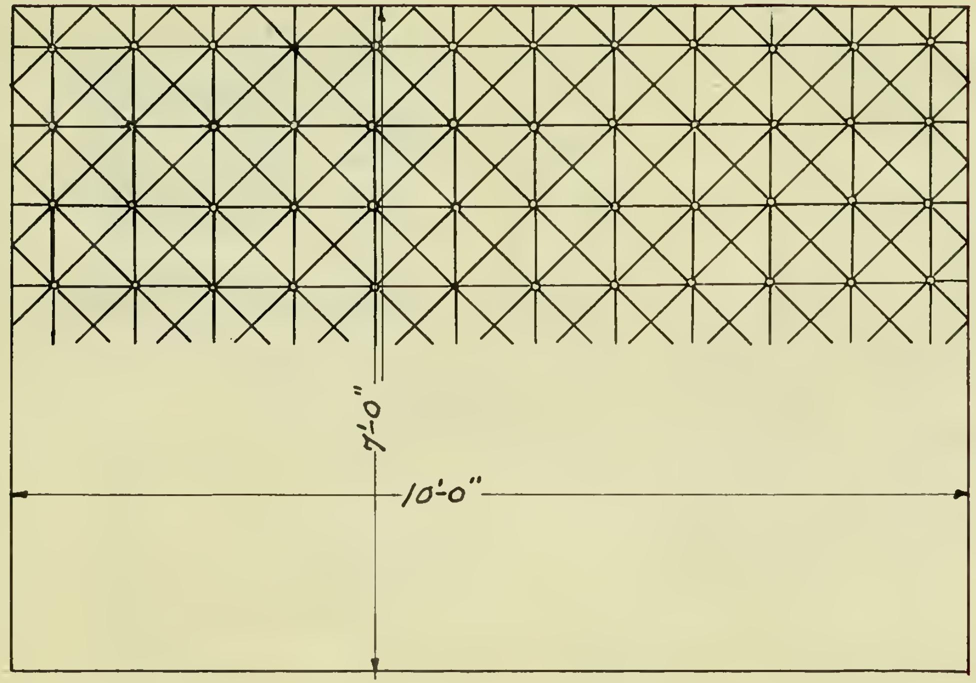
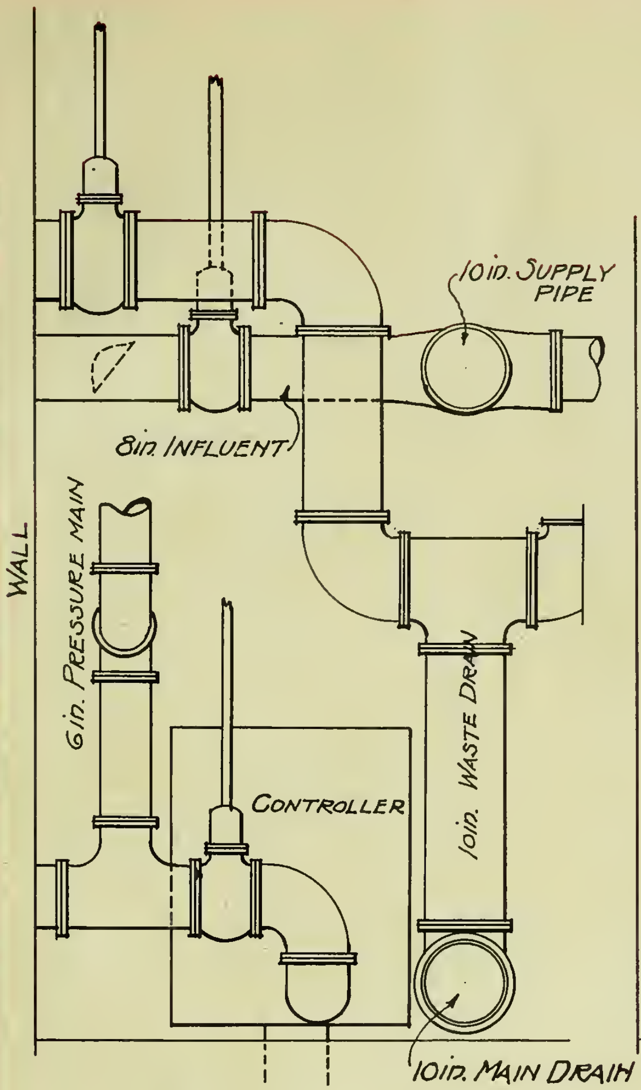
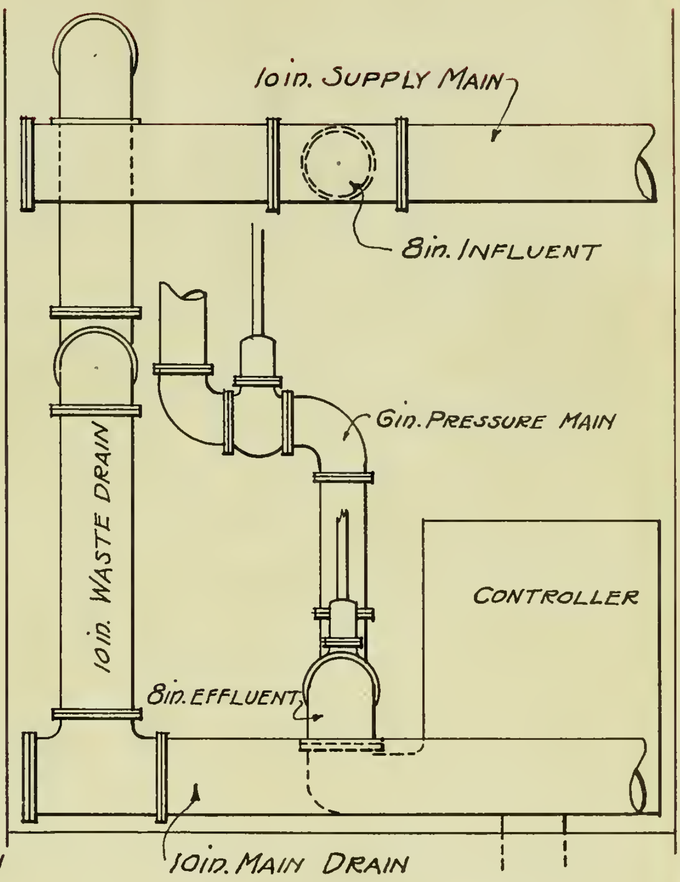


PLATE VI
DETAILS OF FILTER COLLECTOR SYSTEM

SCALE $\frac{1}{2}'' = 1''$



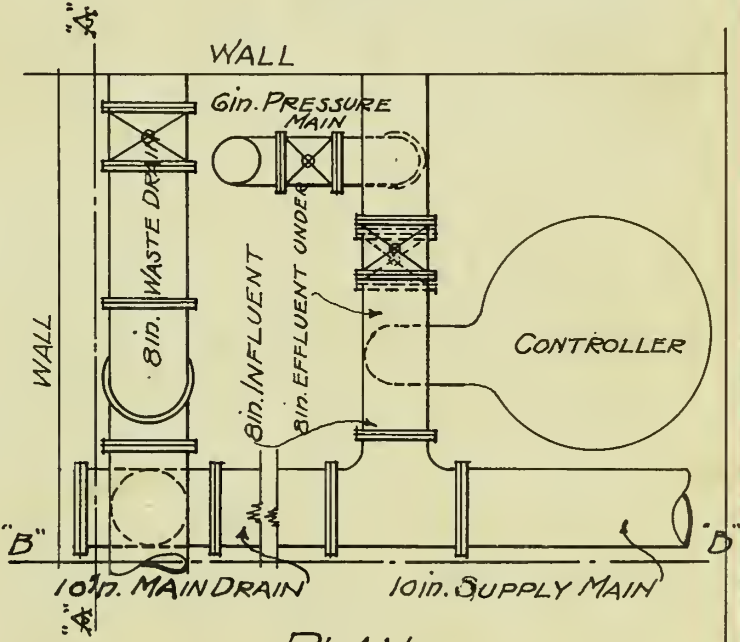
SECTION "A-A"



SECTION "B-B"

PLATE VII
FILTER PIPE CONNECTIONS

·SCALE·1/2"=1'·



PLAN

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